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### Unintended Consequences of the Network-Centric Decision Making Model: Considering the Human Operator

Robert S. Bolia  
Michael A. Vidulich  
W. Todd Nelson

Human Effectiveness Directorate  
Warfighter Interface Division  
Wright-Patterson AFB OH 45433-7022

February 2006

# 20060403505

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Human Effectiveness Directorate  
Warfighter Interface Division  
Wright-Patterson AFB OH 45433

**REPORT DOCUMENTATION PAGE**Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

|   |                           |  |  |  |  |
|---|---------------------------|--|--|--|--|
| <b>1. REPORT DATE (DD-MM-YYYY)</b><br>February 2006   |                           | <b>2. REPORT TYPE</b><br>Technical Paper |  | <b>3. DATES COVERED (From - To)</b>                                      |  |
| <b>4. TITLE AND SUBTITLE</b><br>Unintended Consequences of the Network-Centric Decision Making Model: Considering the Human Operator  |                           |  |  | <b>5a. CONTRACT NUMBER</b>   |  |
|   |                           |  |  | <b>5b. GRANT NUMBER</b>  |  |
|   |                           |  |  | <b>5c. PROGRAM ELEMENT NUMBER</b>  |  |
| <b>6. AUTHOR(S)</b><br>Robert S. Bolia, Michael A. Vidulich, W. Todd Nelson   |                           |  |  | <b>5d. PROJECT NUMBER</b><br>7184  |  |
|   |                           |  |  | <b>5e. TASK NUMBER</b><br>08   |  |
|   |                           |  |  | <b>5f. WORK UNIT NUMBER</b><br>72  |  |
| <b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>   |                           |  |  | <b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>                          |  |
| <b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b><br>Air Force Materiel Command<br>Air Force Research Laboratory<br>Human Effectiveness Directorate<br>Warfighter Interface Division<br>Wright-Patterson AFB OH 45433-7022   |                           |  |  | <b>10. SPONSOR/MONITOR'S ACRONYM(S)</b><br>AFRL/HECP                     |  |
|   |                           |  |  | <b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b><br>AFRL-HE-WP-TP-2006-0044 |  |
| <b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b><br>Approved for public release; distribution is unlimited.   |                           |  |  |  |  |
| <b>13. SUPPLEMENTARY NOTES</b><br>This will be published in the Proceedings of the Command and Control Research and Technical Symposium. The clearance number is AFRL/WS-06-0521, cleared 21 February 2006.   |                           |  |  |  |  |
| <b>14. ABSTRACT</b><br>Although in principle network-centric warfare (NCW) has been embraced by strategic decision makers in the United States and its allies, diverse critiques have begun to appear about the soundness of the construct. Despite this multidisciplinary scrutiny, surprisingly little attention has been paid to the salient human factors questions raised by the paradigm shift. The purpose of this paper is to consider the implications of the network-centric model on individual and team decision making, reflecting in particular on the unintended consequences of network-centric decision making for the human operator. |                           |  |  |  |  |
| <b>15. SUBJECT TERMS</b><br>Cognitive Domain Issues, Social Domain Issues, C2 Experimentation   |                           |  |  |  |  |
| <b>16. SECURITY CLASSIFICATION OF:</b>  |                           |  | <b>17. LIMITATION OF ABSTRACT</b><br>SAR | <b>18. NUMBER OF PAGES</b><br>13   | <b>19a. NAME OF RESPONSIBLE PERSON</b><br>W. Todd Nelson           |
| <b>a. REPORT</b><br>UNC   | <b>b. ABSTRACT</b><br>UNC | <b>c. THIS PAGE</b><br>UNC               |  |  | <b>19b. TELEPHONE NUMBER (include area code)</b><br>(937) 255-8803 |

**2006 CCRTS**  
**THE STATE OF THE ART AND THE STATE OF THE PRACTICE**

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**Topics:** Cognitive Domain Issues, Social Domain Issues, C2 Experimentation

**Authors:** Robert S. Bolia, Michael A. Vidulich, W. Todd Nelson

**Contact:** Robert S. Bolia

**Address:** Air Force Research Laboratory  
AFRL/HECP  
2255 H Street  
Wright-Patterson AFB, OH 45433-7022

Phone: 937-255-8802  
Fax: 937-255-8752  
E-mail: [Robert.Bolia@wpafb.af.mil](mailto:Robert.Bolia@wpafb.af.mil)

Unintended Consequences of the Network-Centric Decision Making Model:  
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Robert S. Bolia  
Michael A. Vidulich  
W. Todd Nelson

*Air Force Research Laboratory*  
*Wright-Patterson Air Force Base, OH*

**Abstract.** Although in principle network-centric warfare (NCW) has been embraced by strategic decision makers in the United States and its allies, diverse critiques have begun to appear about the soundness of the construct. Despite this multidisciplinary scrutiny, surprisingly little attention has been paid to the salient human factors questions raised by the paradigm shift. The purpose of this paper is to consider the implications of the network-centric model on individual and team decision making, reflecting in particular on the unintended consequences of network-centric decision making for the human operator.

All in war is very simple, but the simplest is difficult.<sup>1</sup>

- Carl von Clausewitz

**Introduction.** Network-centric warfare (NCW) is a concept of operations (CONOPS) spawned by rapid advances in information technology, which suggests that a dense networking of sensors and shooters will lead to unprecedented levels of situation awareness, contributing in turn to increased decision speed and self synchronization of forces. Although this vision has been embraced by strategic decision makers in the United States and its allies (Garnett, 2001; Kruzins and Scholz, 2001; Scott & Hughes, 2003; Squire, 2003), critiques have emerged from various quarters, raising questions about the validity of the concept. For example, NCW has been criticized for its basis on a flawed business model (Giffin & Reid, 2003a), its imperfect mathematics (Bolia, Nelson, & Vidulich, *in press*; Giffin & Reid, 2003a), its faulty epistemological foundations (Giffin & Reid, 2003b), its failure to consider relevant historical material (Bolia, Vidulich, Nelson, & Cook, 2006), its technological immaturity (Bolia, 2005; Talbott, 2004), and its implicit rejection of a defense acquisition system based on validated operator requirements (Kaufman, 2005). These analyses notwithstanding, surprisingly little attention has been paid to the salient human factors questions raised by such a paradigm shift. The purpose of this paper is to consider the implications of the network-centric model on individual and team decision making, reflecting in particular on the unintended consequences of network-centric decision making for the human operator. This analysis is based on a reading of the major NCW theorists (Alberts,

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<sup>1</sup> "Es ist alles im Kriege sehr einfach, aber das Einfachste ist schwierig" (Clausewitz, 2002, p. 86). All translations, unless otherwise noted, are the author's.

Garstka, & Stein, 1999; Alberts & Hayes, 2003; Cebrowski & Garstka, 1998), historical analyses on the influence of technology on command and control, and an appreciation of the relevant literature in human factors and social and organizational psychology.

**The Common Operational Picture and Its Exegesis.** The discrepancy between the conception of the common operational picture (COP) and its descriptor recalls Voltaire's edict on the Holy Roman Empire,<sup>2</sup> for it is strictly speaking neither common, nor operational, nor a picture. This incongruity is grounded in part in certain epistemological and ontological questions that are not germane to the subject of this paper.<sup>3</sup> What is relevant is the hermeneutical problem raised by the COP, which has been generally ignored.

The NCW thesis asserts that distribution of the COP will lead to shared situation awareness (SA), from which self-synchronization will inevitably follow (Alberts, Garstka, & Stein, 1999). This is little different than the concept of *Auftragstaktik* promulgated by Moltke in the nineteenth century (Hughes, 1993), or the practice of Nelson's captains at the Nile (Hughes, 2000; Lavery, 1998). Both relied on an inculcated shared mental model of the commander's intent, which, given a correctly apprised situation, would lead to synchronized action.

There are several difficulties with this formula in the context of NCW. The first is the idea of a shared mental model. It is easy to convince oneself that in a network-centric environment the shared mental model is the COP, but this is not the case. The COP is what is interpreted at the operational and tactical levels to build the situational assessment; the shared mental model, instilled by recurrent training, is part of the context in which the COP is interpreted. From this perspective it may be regarded as a prerequisite.

The problem is how to indoctrinate the shared mental model. Moltke's field commanders at Königgrätz, via explicit training and tours on the Prussian General Staff, had been infused with the mental model of their chief (Van Creveld, 1985; Wawro, 1996). It could thus be said that they had a shared mental model – his. Such a transmission, however, would be more difficult to effect across services, and especially across nations. The fact that most modern military operations are conducted by coalitions – often *ad hoc* coalitions – suggests that soldiers, sailors, and airmen fighting together may not possess a shared model.

This is not to say, however, that shared situation awareness is precluded by the failure to develop a shared mental model; only that the precondition considered essential by Moltke may not be met. It is entirely conceivable, for example, that individuals with different mental models may derive the same interpretation of the COP. Does this imply that they have shared SA?

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<sup>2</sup> Voltaire noted, correctly, that the Holy Roman Empire was neither holy, nor Roman, nor an empire : “*Ce corps qui s'appelait et qui s'appelle encore le saint empire romain n'était en aucune manière ni saint, ni romain, ni empire*” (Voltaire, 1990).

<sup>3</sup> Some of these are addressed in Giffin & Reid, 2003b; and Lambert & Scholz, 2005.

Unfortunately, this question is not an easy one, since an accepted definition of shared SA is lacking. Endsley (1995), for example, defines *team SA* as the degree to which all of the team members have sufficient individual SA to perform their required tasks. However, this does not necessarily imply a *sharing* of SA. If two geographically separated brigade commanders, looking at their portion of the COP, decide to attack the enemy in their front simultaneously, this represents synchronized action but not necessarily shared SA. Indeed, it does not even suggest collaboration, since one brigadier may not even be aware that the other is attacking.

Of course, this does not rule out shared SA as a possibility. If the same two brigade commanders held adjacent commands but were prevented from communicating, one might decide to attack given a COP comprising both brigade areas and the knowledge that his colleague, trained to the same mental model, would surely also do so. In this case the shared mental model provides the hermeneutical context for both the commander's vision of the situation and his understanding of colleague's interpretation thereof. It is this variety of SA that is viewed as desirable not only by SA theorists in conflict with Endsley's view of "team SA" (Salmon, Stanton, Walker, & Green, 2006), but also by the advocates of NCW.

The problem is that this conception makes two tacit assumptions that are not guaranteed to be met. The first is that a shared mental model will lead to a shared interpretation of the COP. The second is that the shared interpretation of the COP will lead to a shared interpretation of what is a correct course of action. Regrettably, military history is replete with situations in which one or both of these conjectures proved false. What is difficult to prove in these cases is whether the failure was due to fallacious reasoning, or to the lack of a shared mental model.<sup>4</sup> Regardless, this may present a major human factors challenge for the implementation of the network-centric CONOPS, which will only be exacerbated by adversary-induced uncertainty and information overload.

**Information, Uncertainty, and their Display.** One of the key assertions made by NCW theorists is that advances in technology will afford the provision of more information to operators at every level of the sensor-to-shooter chain, leading to an almost complete elimination of uncertainty, hence higher levels of situation awareness, hence improved mission execution (Alberts & Hayes, 2003). There are at least two problems with this position.

The first is the idea, current among technophiles (see, for example, Owens, 2000), that uncertainty is an artifact that can be somehow excised from warfare, and that the way to achieve its removal is by adding more information, that is to say, more sensors. Although it is impossible to demonstrate the truth or falsity of this proposition either logically or

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<sup>4</sup> For example, it is likely that Montgomery and Patton had a shared awareness of the operational situation in the autumn of 1944 (Hastings, 2004), yet promoted different avenues of attack. Is this because they lacked a shared mental model? Or is it because each wanted to be the first to drive into Germany? Can these two options even be disentangled?

empirically, it should certainly not be assumed as given. Indeed, the prevailing view has been contrary. Clausewitz, for example, has noted that "War is the territory of chance. No other human activity gives this stranger so much room to maneuver, because no other has on all sides such constant contact with him. Chance multiplies the uncertainty of all circumstances and interferes with the course of events" (Clausewitz, 2002, p. 64).<sup>5</sup> Moreover, current theories of science regard uncertainty as a property not only of warfare, but of the physical world (Heisenberg, 1973; Margenau, 1950).

The second problem is with the implicit assumption that more information is necessarily better. This suggests that poor decisions have historically been the result of a dearth of information, which has not always been the case. In the 1973 Yom Kippur War, for example, the failure of Israeli intelligence to anticipate the Egyptian and Syrian attacks was not due to a lack of information, but to the interpretation of the information available in the context of an inappropriate shared mental model of Arab intentions (Bolia, 2004).

This assumption also evokes the idea of quantity over quality, but the quality of the data must also be taken into account. Clausewitz, writing in the early nineteenth century, observed that "a greater part of intelligence reports that one receives in war are contradictory; a still greater part are false, and nearly all are subject to uncertainty" (Clausewitz, 2002, p. 84).<sup>6</sup> While these proportions may have altered over the course of two centuries, the gist of the assertion remains valid.

There are several respects in which the quality of the information destined for presentation to the operator may be compromised. First, it may be inaccurate due to faulty sensors or to an imperfection in the software by which it is processed. The latter is a concern in data fusion and tracking systems, since spurious or dropped tracks could result in a loss of SA. Second, the enemy may mount a deliberate deception campaign, filling the network with illusory tracks or misleading intelligence. Finally, there is the problem of knowing what is missing. The continuous availability of vast amounts of information imparts an illusion of completeness. This is a problem, because the operator may know what he knows, but will not always know what he does *not* know. The COP provides few if any clues as to what is *not known* about red or blue force elements. If an object is not displayed, it may be that it does not exist in the battlespace, but it may also be that it has eluded the sensors, or that its transponder is malfunctioning. If an operator does not recognize that information is missing, he likely knows neither that he needs it nor where to look for it.

While matters of information quality are certainly paramount, the quantity of information also needs to be considered, especially with respect to the human operator's limited capability to process it. Although the network-centric CONOPS may lead to a substantial increase in the amount of information available, it is not likely to engender a concomitant

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<sup>5</sup> "Der Krieg ist das Gebiet des Zufalls. In keiner menschlichen Tätigkeit muß diesem Fremdling ein solcher Spielraum gelassen werden, weil keine so nach allen Seiten hin in beständigen Kontakt mit ihm ist. Er vermehrt die Ungewißheit aller Umstände und stört den Gang der Ereignisse."

<sup>6</sup> "Ein großer Teil der Nachrichten, die man im Kriege bekommt, ist widersprechend, ein noch größerer ist falsch und bei weitem der größte einer ziemlichen Ungewißheit unterworfen."

increase in the operator's attentional capacity. If too much information is presented at once, the operator will not be able to completely assimilate or analyze it, and there is no guarantee that the information lost will have been the least critical.

**Automation and its Accidental Consequences.** One means of averting information overload is to automate much of the processing that might otherwise encumber the human. Levels of automation vary (Parasuraman, Sheridan, & Wickens, 2000), of course, from automated data fusion and entity tracking at one end of the spectrum, to a middle ground of automated decision support, to fully autonomous combat vehicles. Lamentably, they may all be a factor in grave, yet inadvertent consequences.

There is an extensive literature on the performance effects on humans interacting with automated systems (for a recent review in the context of aviation, see Parasuraman & Byrne, 2003). Studies suggest that the automation of a task or set of tasks can change the perceptual and cognitive demands of the operator, and may lead to skill degradation (Parasuraman & Riley, 1999). This can be especially awkward when the automation system fails – for example, during a network outage – and humans are compelled to perform a typically automated task manually (or cognitively).

The other major human factors issues associated with the use of automated systems revolve around the question of trust in the automation. On the one hand, if users do not trust an automated system, either because it is novel or because it is unreliable, they will not use it. On the other hand, users of highly reliable automated systems quickly build trust in them, to the point at which, if the systems fail in way that is not manifested overtly, the users will not notice. This is symptomatic of a phenomenon known as automation-induced complacency (Parasuraman & Riley, 1999). The failure of a highly reliable tracker, for example, could engender a loss of track continuity, which may lead to a failure to engage the enemy, or even the accidental engagement of one's own forces.

**Perturbing the Levels of War.** At least since the time of Moltke, military theorists have distinguished three levels of war – the strategic, the operational, and the tactical – corresponding to three stages of military decision making (Hughes, 1993). Because the consequences of decisions made at each level differ vastly in magnitude, decision authority is conferred based on military rank, which is expected to vary directly – due to training as well as selection – with expertise at these levels.

It should also be obvious that these stages have different time courses, which allow for different decision making methodologies. Decision making at the strategic level is typically construed as a rational process involving the detailed analysis of a series of courses of action (COA). The decision then corresponds to the selection of the optimal COA (Bryant, Webb, & McCann, 2003). At the tactical level, there is no time for such exhaustive examination. Here decision making is said to be "recognition-primed" (Klein, 1997), and is characterized by an intuitive response to a Gestalt recognition of the situation, analogous to the *coup d'oeil* described by Clausewitz (2002). One noteworthy



characteristic of the recognition-primed decision making model is that it emphasizes decision speed over decision quality, and hence seeks a "satisficing" rather than an optimizing decision. A model for operational decision making has not been as well described, but may be imagined as a hybrid of the two (Bryant, Webb, & McCann, 2003).

Under the NCW thesis, the divisions between the three levels of war become obscured. As decision quality information is made available to all echelons of the command chain, decision authority will be pushed down to lower levels in order to expedite prosecution of an increasing quantity of time-critical targets, a concept known in network-centric parlance as "power to the edge" (Alberts & Hayes, 2003). But the conferral of authority upon the "edge" of the military organization is meaningless unless the level of expertise is there. It is not enough to argue that, since more decisions will be made at the tactical level, tactical decision making skills will be sufficient for the job, since now the tactical decision makers will need to have a clear understanding of the operational and strategic implications of their decisions.

It has been proposed that these issues will be resolved in part by the use of automated decision support systems. There are at least two challenges to this argument. First, context-sensitive decision support is one of the most challenging problems in computer science, even for problem domains significantly less complex than combat operations (Bolia, 2005; Bolia, Nelson, Vidulich, & Taylor, 2004). A useful COA generator for tactical commanders is likely to be years, if not decades away. Second, the use of decision support systems will change the cognitive demands of the decision task in ways that are not predictable. One of the possible consequences is that tactical decision makers using these systems will sacrifice speed of decision for perceived optimality.

**Authority and Responsibility.** Another claim that can be made with respect to NCW is that it obfuscates the division of command. By providing access to a detailed common picture at all strata of the command chain, the network-centric model encourages decision making at inappropriate levels. For example, a corps commander may be able to "zoom in" on the situational picture at the platoon level, and, believing he has a correct view of the situation, give direct orders to the platoon leader. Not only does micromanagement of this ilk circumvent the normal command chain, potentially causing confusion at intermediate echelons, it also makes assumptions about the accuracy and legitimacy of the COP that, for reasons discussed above, may not hold. It is also contrary to the doctrine of *Auftragstaktik*, which, grounded in Moltke's idea that "no plan outlives the first contact with the enemy,"<sup>7</sup> suggests that the commander closest to the front is the best equipped to make the decisions.

Although likely to be less frequent, this problem may also appear at the other end of the command chain, for the same reason. A commander at the tactical level, able to "see the whole picture," may decide to modify the plan not in response to enemy action, but because he believes doing so will create a desired effect in a different part of the

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<sup>7</sup> "Kein Plan überlebt die erste Feindberührung."

battlespace. In this case, the subordinate officer does not have the authority for altering the plan, but has the information required to do so.

One other concern is that the distribution of decision making – and in some cases the uncertainty about where decisions will be made – will allow commanders to distribute not authority, but responsibility. If an operation goes well, this may not be an issue, but in the event of failure it may lead to pervasive buck passing.

**Teamwork and Distributed Collaboration.** One of the pervasive themes found in the writings on NCW is that of distributed collaboration across the network. Connectivity allows the sharing of information, the sharing of intent, the sharing of SA, and, presumably, collaborative engagement. Significantly, NCW not only *allows* this type of sharing, it requires it. This is more than a subtle distinction.

Recent reviews have begun to address the hypothetical impact of NCW doctrine on team performance and the measurement thereof (Best & Skinner, *in press*; Nelson, Bolia, & Vidulich, *in press*). They are not exhaustive, however, and fail to remark on two potentially serious topics which may be impacted by NCW: trust and leadership.

Trust is an important component of effective teamwork. If team members do not trust one another, the team will not function smoothly. The question is then whether *ad hoc* distributed teams, whose members retain a high level of anonymity due to lack of socialization, will be able to build a degree of trust similar to that obtained by teams operating in a face-to-face environment. The same question arises with respect to leadership, which, despite calls of “power to the edge,” will continue to play a critical role in military operations. Not only is leadership dependent on trust, it is also accepted that good military leaders build this trust by personal interaction with their troops (Puryear, 2003). Needless to say, a willingness to risk one’s life for a commander is less likely to be inculcated by an instant messaging session than by personal dealings.

**Training and Selection.** The lack of novelty of many of the bases of NCW should not lead to the hasty conclusion that it is not an entirely different form of warfare. If taken to its logical conclusion, NCW would revolutionize the way wars are fought, beginning with a devaluing of the command chain. Yet although this will doubtlessly lead to a requirement for a new breed of soldier, sailor, and airman, little has appeared in the literature on the selection and training of this breed.

With respect to training, Best & Skinner (*in press*) have done an admirable job of discussing traditional training human factors issues in the context of the network-centric CONOPS. Still, questions remain. For example, how does one train the shared mental model required by the revision of *Auftragstaktik*; or train lieutenants to make decisions previously made by lieutenant generals; or train skeptical young officers to trust people they have only met online?

Selection may prove to be at least as important an issue. The doctrine of "power to the edge" highlights the "strategic corporal" as a player in network-centric operations (Alberts & Hayes, 2003). The idea of personnel without even the equivalent of a high school diploma making decisions with strategic consequences suggests that much more consideration needs to be given to the problem of who will be fighting the wars of the future.

**Conclusion.** Nearly a decade has passed since the late Admiral Cebrowski proclaimed the virtues of NCW to the world. In that time, the doctrine has continued to grow, to the point at which its adherents declare that its attainment of fruition is only limited by appropriate investments in the technology. Yet this is the claim of a network-centric band, who have failed to recognize that warfare is *human-centric*. Unless and until the relevant human factors questions are addressed, NCW will continue to be little more than a utopian dream.

## References

- Alberts, D. S., Garstka, J. I., & Stein, F. P. (2000). *Network-centric warfare: Developing and leveraging information superiority*. Washington: Command & Control Research Program.
- Alberts, D. S., & Hayes, R. E. (2003). *Power to the edge: Command... control... in the information age*. Washington: Command & Control Research Program.
- Barnett, T. P. M. (1999). The seven deadly sins of network-centric warfare. *Proceedings of the US Naval Institute*, January, 36-39.
- Best, C., & Skinner, M. (in press). Training for network-centric air operations. *International Journal of Aviation Psychology*.
- Bolia, R. S. (2005). Intelligent decision support systems in network-centric military operations. *Intelligent Decisions? Intelligent Support? Pre-proceedings for the International Workshop on Intelligent Decision Support Systems: Retrospects and Prospects*, 3-7.
- Bolia, R. S. (2004). Over-reliance on technology in warfare: The Yom Kippur War as a case study. *Parameters*, 34 (3), 46-56.
- Bolia, R. S., Nelson, W. T., & Vidulich, M. A. (in press). Network-centric operations and the obfuscation of the levels of war. In R. S. Bolia & R. M. Taylor (Eds.), *Supporting decision effectiveness in network-centric operations: Theory and applications*. Wright-Patterson Air Force Base, OH: Human Systems Information Analysis Center.
- Bolia, R. S., Nelson, W. T., Vidulich, M. A., & Taylor, R. T. (2004). From chess to chancellorsville: Measuring decision quality in military commanders. In D. A. Vincenzi, M. Mouloua, & P. A. Hancock (Eds.), *Human performance, situation awareness, and automation: Current research and trends*, Vol. I (pp. 269-273). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Bolia, R. S., Vidulich, M. A., Nelson, W. T., & Cook, M. J. (2006). The use of technology to support military decision-making and command & control: A

- historical perspective. In Cook, M. J., Noyes, J. M., & Masakowski, Y. (Eds.), *Decision Making in Complex Systems*. Aldershot, UK: Ashgate Publishing Ltd.
- Bryant, D. J., Webb, D. G., & McCann, C. (2003). Synthesizing two approaches to decision making in command and control. *Canadian Military Journal*, 4 (1), 29-34.
- Cebrowski, A.K., and Garstka, J.J. (1998), 'Network-centric warfare: Its origin and future', *U. S. Naval Institute Proceedings*, 124 (1), 28-35.
- Clausewitz, C. von. (2002). *Vom kriege*. Berlin: Ullstein.
- Endsley, M. R. (1995). Towards a theory of situation awareness in dynamic systems. *Human Factors*, 37, 32-64.
- Garnett, G. (2001), 'The Canadian Forces and the revolution in military affairs: A time for change', *Canadian Military Journal*, 2 (1), 5-10.
- Giffin, R. E., & Reid, D. J. (2003a). A woven web of guesses, canto one: Network centric warfare and the myth of the new economy. *Proceedings of the 8<sup>th</sup> International Command and Control Research and Technology Symposium*. Washington: Command and Control Research Project.
- Giffin, R. E., & Reid, D. J. (2003b). A woven web of guesses, canto two: Network centric warfare and the myth of inductivism. *Proceedings of the 8<sup>th</sup> International Command and Control Research and Technology Symposium*. Washington: Command and Control Research Project.
- Hastings, M. (2004). *Armageddon: The battle for Germany, 1944-1945*. New York: Alfred A. Knopf.
- Heisenberg, W. (1973). Development of concepts in the history of quantum mechanics. In J. Mehra (Ed.), *The physicist's conception of nature*, pp. 264-275. Dordrecht & Boston: D. Reidel Publishing.
- Hughes, D. J., ed. (1993). *Moltke on the art of war: Selected writings*. New York: Ballantine Books.
- Hughes, W. P. (2000). *Fleet tactics and coastal combat*. Annapolis. U. S. Naval Institute Press.
- Kaufman, A. (2005). Caught in the network: How the doctrine of network-centric warfare allows doctrine to dictate military strategy. *Armed Forces Journal*, February, 20-22.
- Klein, G. (1997). The recognition-primed decision model: Looking back, looking forward. In C. E. Zsombok & G. Klein (Eds.), *Naturalistic decision making* (pp. 285-292). Mahwah, NJ: Lawrence Erlbaum Associates.
- Kruzins, E., and Scholz, J. (2001). Australian perspectives on network centric warfare: Pragmatic approaches with limited resources. *Australian Defence Force Journal*, 150, 19-33.
- Lambert, D. A., & Scholz, J. B. (2005). A dialectic for network centric warfare. *Proceedings of the 10<sup>th</sup> International Command and Control Research and Technology Symposium*. Washington: Command and Control Research Program.
- Lavery, B. (1998). *Nelson and the Nile: The naval war against Bonaparte 1798*. London: Claxton Editions.
- Margenau, H. (1950). *The nature of physical reality*. New York: McGraw-Hill.
- Nelson, W. T., Bolia, R. S., & Vidulich, M. A. (in press). Assessing teams and decision making in network-centric tactical air battle management: Methodological issues. *International Journal of Aviation Psychology*.

- Owens, B., with E. Offley (2000). *Lifting the fog of war*. New York: Farrar, Straus, and Giroux.
- Parasuraman, R., & Byrne, E. A. (2003). Automation and human performance in aviation. In P. S. Tsang & M. A. Vidulich (Eds.), *Principles and practices of aviation psychology* (pp. 311-356). Mahwah, NJ: Lawrence Erlbaum Associates.
- Parasuraman, R., and Riley, V. R. (1999). Humans and automation: Use, misuse, disuse, abuse. *Human Factors*, 39, 230-253.
- Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, & Cybernetics*, 30, 286-297.
- Puryear, E. F. (2003). *Nineteen stars: A study in military character and leadership*. New York: Presidio Press.
- Salmon, P., Stanton, N., Walker, G., & Green, D. (2006). Situation awareness measurement: A review of applicability for C4i environments. *Applied Ergonomics*, 37, 225-238.
- Scott, W.B., and Hughes, D. (2003). Nascent net-centric war gains pentagon toehold. *Aviation Week and Space Technology*, 158 (4), 50-53.
- Squire, P. (2003), 'Air Power into the 21<sup>st</sup> Century', *Air Power Review*, 6 (1), 1-9.
- Talbot, D. (2004). "We Got Nothing Until They Slammed Into Us." *Technology Review*, November, 36-45.
- Toomey, C.J. (2003). Army digitization: Making it ready for prime time. *Parameters*, 24 (4), 40-53.
- Van Creveld, M. (1985). *Command in War*. Cambridge, MA: Harvard University Press.
- Voltaire (1990). *Essai sur les moeurs et l'esprit des nations et sur les principaux faits de l'histoire depuis Charlemagne jusqu'à Louis XIII* (2 vols). Paris: Garnier.
- Wawro, G. (1996). *The Austro-Prussian war: Austria's war with Prussia and Italy in 1866*. Cambridge, UK: Cambridge University Press.